Cigarette Smoking, Physical Activity and Time Use

GREGORY COLMAN

gcolman@pace.edu
Department of Economics
Pace University & NBER
New York, NY 10038

KAREN SMITH CONWAY*

karen.conway@unh.edu
Department of Economics
University of New Hampshire
Durham, NH 03824

DHAVAL DAVE

ddave@bentley.edu
Department of Economics
Bentley University & NBER
Waltham, MA 02452

This study adds to the limited, existing research on the relationship between cigarette costs, smoking and physical activity by considering more comprehensive physical activity measures, including non-work activities beyond recreational exercise. To better understand the relationship between smoking and our broader measures of physical activity, we provide a conceptual framework in which smoking takes time and is often a secondary activity that is easier to undertake during some activities (e.g., watching television, walking) than others (running). These measures come from the American Time Use Survey (ATUS), linked with the Current Population Survey's Tobacco Use Supplement (CPS-TUS), for 2003-2012, a period of increasing cigarette costs yet predating the emergence of e-cigarettes. Our empirical results suggest that the relationships between cigarette costs, smoking and physical activity are different between men and women and that focusing only on 'exercise,' rather than all forms of non-work, physical activity may yield misleading conclusions. Smoking cessation is associated with increased 'exercise' for both men and women, but only men's smoking and exercise are significantly affected by cigarette prices. However, redefining physical activity to include other non-work activities eliminates these relationships, suggesting few spillovers between smoking and physical activity, once broadly defined. Even if cigarette costs induce an increase in exercise – as they appear to do for males – this increase comes at the expense of other activities, thereby diminishing the overall impact on physical activity.

Keywords: Smoking, physical activity, cigarette price, exercise, tobacco, quit

JEL Code: I12, J22

* Corresponding Author

I. Introduction

Maintaining a healthy weight, engaging in regular and vigorous physical activity and not smoking are widely regarded as the most effective pathways to good health and improved life expectancy. However, it is not clear – either theoretically or empirically -- how individuals make decisions regarding these potentially complementary and compensating behaviors. Numerous studies have empirically investigated spillover effects on obesity from policies to reduce smoking[1], whereas far less is known about the possible effects on other compensatory behaviors, such as exercise. Exercise has a potentially complicated relationship with smoking, as both behaviors may help manage weight but have conflicting effects on health. Moreover, many activities beyond formal exercise require physical exertion and so may also yield these benefits. How individuals allocate their time across these activities and how their possible health benefits or decisions about smoking play a role is far from clear. Given the importance of physical activity to long term health and the fact that nearly 80% of Americans do not get the recommended amount each week (Blackwell and Clarke 2018), understanding the effects of tobacco policies on all types of physical activity and formal exercise in particular is critical to evaluating their efficacy in improving overall health.

Economic research on the relationship between tobacco policy and adult physical activity is quite limited, yielding mixed results and being based only on measures of exercise available in the Behavioral Risk Factor Surveillance System (BRFSS; Courtemanche 2009, Wehby and Courtemanche 2012 and Conway and Niles 2017).[2] Our study makes several contributions in an

[1] See for example Chou et al (2004), Gruber and Frakes (2006), Baum (2009), Courtemanche (2009), Nonnemaker et al (2009), Sen and Wilson (2010) and Wehby and Courtemanche (2012). The conclusions from this research are mixed with most finding either positive or statistically insignificant effects of cigarette taxes/prices on BMI/obesity. The first order effect – that cigarette taxes/prices reduce smoking – has been studied even more extensively and has arrived at a greater consensus that such policies do reduce smoking at both the extensive and intensive margins (e.g., Chaloupka and Warner 2000, Tauras 2006 and DeCicca and McLeod 2008).

[2] As discussed in more detail shortly, the BRFSS survey questions refer broadly to formal exercise ('running, calisthenics', etc.), sports ('golf') and some other chore-related physical activity ('yard work'). Its main stipulation is that it not be related to one's job. As such it is neither a measure of formal exercise, performed with the goal of health or recreation, nor an all-encompassing measure of physical exertion. In addition, the more detailed follow-up questions about the duration, frequency and types of activities were dropped from the 2001-2010 surveys.

attempt to close this gap. With data from the American Time Use Survey (ATUS) for 2003-2012, we construct more current, comprehensive and precisely defined measures of physical activity and exercise than those used in previous work. Using post-2000 data provides a critical update to past research, as the BRFSS did not ask detailed exercise questions during 2001-10. The 2000s saw much greater variation in, and higher levels of, cigarette taxes than in previous years, which helps identify empirically their effects on physical activity and makes a behavioral response more likely than in past years when such taxes were relatively low. The 2003-2012 period also predates the emergence and widespread use of e-cigarettes, which simplifies the possible, causal pathways for cigarette costs to have an effect.[3] With its time diary construct, the ATUS can measure more precisely both the duration and intensity of physical activity and can distinguish if the physical activity came from work behavior, formal exercise or other types of activities.

Studying these more detailed, comprehensive measures of physical exertion requires a richer conceptual framework, one recognizing that formal exercise may be substituted for or reinforced by shifts in other activities and that all activities may potentially be affected by smoking behavior and thus tobacco policy. Our framework contributes to the understanding of smoking behavior and tobacco policies more broadly by considering that smoking takes *time* and can be performed simultaneously with some activities but not others. We take advantage of the smoking data available in the Current Population Survey Tobacco Use Supplement (CPS-TUS), which can be combined with a subset of the ATUS, to create a rich dataset that includes detailed information about both smoking history and behavior as well as all primary physical activities. This data allows us to estimate first-stage effects and structural models as well as the reduced form models of exercise typically estimated.

Our empirical results suggest key differences between men and women. We find that increased cigarette costs increase exercise for men but have little effect for women. This difference appears primarily driven by first-stage effects; men's smoking is significantly reduced by increased cigarette prices whereas women's is not. Therefore, while both men and women exercise more if they have quit smoking, only men's quitting behavior appears significantly affected by cigarette prices. Our analyses also reveal that formal exercise is only a small part of total physical activity, and that smoking behavior is associated with differences in these other activities as well.

[3] E-cigarette use among young adults ages 18-34 was only 1.7% in 2012; it rose to 10.8% by 2014 (Dave et al. 2019).

Analyses on total non-work physical activity and different categories suggest that the effects we find for exercise are a reallocation of exertion from other activities such that overall physical activity is not affected. This finding underscores the importance of considering both formal exercise and more comprehensive measures of physical activity in studying the possible spillover effects of tobacco policy.

II. Past Research

The presumed conduit for cigarette costs to have an effect on health behaviors is through their effects on smoking. Such effects have been extensively investigated in past research (Chaloupka and Warner 2000; Cawley and Ruhm 2011). Cigarette taxes and prices are consistently found to reduce smoking, even among older smokers (e.g., DeCicca and McLeod 2008), thereby raising the possibility of spillover effects to other health behaviors and outcomes, most notably obesity and BMI.[4] Beginning with Chou et al (2004), numerous studies investigate the effect that cigarette taxes and prices have on obesity and find mixed results (see footnote 1). Two of these studies, Courtemanche (2009) and Wehby and Courtemanche (2012), go a step further by also searching for effects on health *behaviors* such as diet and exercise in supplementary analyses. Using data from the BRFSS through 2000, both provide evidence that increased cigarette prices increase exercise.

Conway and Niles (2017) are the first to make the effects of cigarette taxes/prices on exercise the central focus.[5] They construct a theoretical framework that reveals the potentially conflicting effects that smoking – and by extension tobacco policy – has on exercise behavior. Smoking impairs the ability to (increases the disutility from) exercise, suggesting that increasing cigarette prices should increase exercise, as found previously. However, smoking and exercise are also two critical inputs into the health production function. Individuals may therefore compensate for a reduction in smoking by decreasing other health-promoting activities such as exercise.[6]

[4] Note that even if cigarette taxes do not reduce smoking, they can still exert income effects on other behaviors.

[5] They provide a thorough summary of research into smoking and related behaviors and outcomes, especially exercise, so we do not repeat that here. See also Kaczynski et al (2008) for a review of observational evidence on the relationship between smoking and exercise.

[6] Conway and Niles (2017) also note that exercise and smoking are ways to manage one's weight, as distinct from overall health. In that case, the compensating change in exercise moves in the opposite direction; exercise is increased

Conway and Niles (2017) note that such 'Compensating Health Beliefs' (CHBs) are investigated within health psychology research, including the relationship between smoking and exercise (e.g., Radtke et al 2011). They also summarize scientific evidence of the improvements in health associated with exercise, many of which run counter to the damage caused by smoking and thus lends support to such beliefs. These health benefits include improved pulmonary function and life expectancy and reduced risk of cardiovascular disease and many cancers (e.g., deRuiter and Faulkner 2006). Using measures of exercise from the BRFSS that capture both time spent and intensity (up through 2000), the authors consistently find that higher cigarette taxes reduce exercise. Sen Choudhury and Conway (2020) extend this research to adolescents, using data from the Youth Risk Behavior Surveillance System (YRBSS) and also find that higher cigarette taxes reduce exercise. These two studies therefore support the notion of CHBs and contradict those in Courtemanche (2009) and Wehby and Courtemache (2012).

All three studies of adult exercise and cigarette costs use measures of exercise created from the BRFSS. The specific question asked of respondents is

> "The next few questions are about exercise, recreation, or physical activities other than your regular job duties. During the past month, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?"

This measure clearly excludes physical activity at work, but is otherwise vague as to how physical activity or exercise is defined. The end of the question suggests that the goal of the activity is 'for exercise.' Yet, the possible activities listed in the follow-up questions include carpentry, fishing, mowing the lawn, painting/papering the house and snow shoveling; at the same time, other household production activities requiring physical exertion, such as sweeping, vacuuming, cleaning and child care activities, are not listed. Critically, the follow up questions are not asked in 2001-2010, such that these studies either end in 2000 or only use the main question above.

---

to compensate for the likely weight gain resulting from reduced smoking. Thus, individuals' compensatory behavior depends on their health goal.

As described in more detail in Section IV, the ATUS allows us to identify the primary activity, and thus the likely associated physical exertion, undertaken by the respondent during a 24 hour period. Taking this broader view of physical activity raises several questions, including whether the individual considers the physical exertion required at work or in their household activities when deciding on formal exercise and how best to define 'formal exercise' when many of these household activities are likely voluntary.[7] Colman and Dave (2013) tackle these issues in their study of the effects of the business cycle on overall physical activity.[8] In their conceptual model, both formal exercise and other non-sedentary activities help produce health, but the former is more productive and the latter yields greater direct utility. Using data from the ATUS, they find that while these physical activities all increase when work time decreases, they do not make up for the loss in work-related physical exertion. Therefore, total physical activity declines with unemployment.

The role of smoking also becomes more complicated, as some of these activities preclude smoking (running, playing sports with one's kids) while others may complement it (walking, gardening, fishing, cleaning the house). This point recognizes that smoking requires time as well as cigarettes, time that sometimes can be spent simultaneously on another activity as well. Such multi-tasking, also known as secondary, overlapping or polychronic activities, has been mostly overlooked in economic studies with the exception of a few that consider primarily household tasks such as child care and housekeeping (e.g., Floro and Miles 2003; Kalenkoski and Foster 2010). Kalenkoski and Foster (2010) claim to devise the first multitasking model of household production; they model childcare and housework as each being functions of sole and multi-tasking time.

---

[7] For example, one can imagine that the health benefits of mowing the lawn may enter into the decision of whether or not to hire someone else to complete the task.

[8] This study in turn builds on the more extensive economic research that explores whether recessions can be beneficial for health through relaxing time constraints (e.g., Ruhm 2005). See also Meltzer and Jena (2010) who point out that individuals may adjust the *intensity* of their exercise in response to time constraints and higher wages. Humphreys and Ruseski (2011) embed the decision to participate in physical activity within an optimizing model of labor and leisure, and find that the demand for physical activity – both at the extensive and intensive margins – responds to income and time constraints.

To our knowledge, no study has investigated explicitly, either empirically or theoretically, smoking as a polychronic activity, although Adda & Cornaglia (2010) come close. They investigate the effects of smoking bans on smoking behavior and in particular the possibility that bans displace smoking to private places, thus leading to increased exposure for nonsmokers, especially children. Their theoretical model includes time spent smoking, which comes from time spent at home or (in the absence of bans) in bars or at work. With a number of simplifying assumptions, the authors then show that smoking bans increase the optimal amount of time spent at home.[9] Their empirical analyses confirm this result, finding that smoking bans lead to more time spent at home and greater exposure to smoke by children. No study, to our knowledge, has considered exercise or physical activity as a polychronic activity.

III. Conceptual Framework

Our conceptual framework borrows key insights from Colman and Dave (2013) and Conway and Niles (2017), as well as the smoking ban and smoking intensity models of Adda and Cornaglia (2006, 2010). Exercise is modeled as one of many activities that affect utility both directly and indirectly through health. Smoking also affects utility both directly and indirectly through health and is modeled as a secondary activity that is undertaken simultaneously with another. Note that if 'activity' is defined broadly enough (e.g., sitting), this framework includes smoking as the 'primary' activity in the usual sense. Some activities preclude smoking and others limit the amount of time or intensity of smoking.

The individual is assumed to maximize utility, which is a function of time spent on a wide set of activities, denoted as n-vector *TA*, the corresponding smoking activity (n-vector *S*), health *H* and a composite consumption good *Y*,

$$U = U(TA, S, H, Y).$$

Health is a function of the activities, smoking and medical inputs *M*,

$$H=H(TA, S, M).$$

[9] These simplifying assumptions include a utility function that is separable in cigarettes and time spent smoking, which ignores that smoking is a function of both time spent *and* cigarettes.

This framework incorporates and extends the insights of Colman and Dave (2013) by allowing for a full range of activities, from vigorous, unpleasant exercise that presumably produces large health benefits ($\partial H/\partial TA >> 0$) while its direct impact on utility is negative ($\partial U/\partial TA < 0$) to leisure activities that provide little or no health benefit but have large direct effects on utility. In Colman and Dave (2013), non-work activities are divided into two groups, formal exercise (*EX*, which is the former extreme) and other non-sedentary activities (*TZ*, the latter extreme). In fact, the range of possible activities encompass all combinations (unpleasant activities that harm one's health) but utility-maximizing behavior suggests that individuals only choose those that promote health, directly increase utility or do both. In this framework, we include time spent at work as the *nth* activity, which generates income in addition to affecting utility and health.

Adding smoking to the utility and health production functions borrows from Conway and Niles (2017); another insight is that *H* can either be general health (on which smoking has a negative effect) or weight management (on which it has a positive one). Finally, we note that *H(.)* is what the individual considers when making decisions, not the actual underlying health production function. Whether or not individuals actually consider the health benefits from all activities requiring physical exertion (e.g., vacuuming) is not clear. A certain activity, TA_n, may therefore have a low weight in *H(.)* either because it is unproductive or because the individual does not recognize its health benefits.

To recognize that smoking takes time and that activities vary in their ability to accommodate smoking as a secondary activity, we define *S* as a vector of *N* smoking behaviors, each corresponding to one of the primary activities. Similar to Adda and Cornaglia (2006), we model smoking as a function of cigarettes smoked (C_n) and intensity (I_n), as well as the time spent on activity *n*,

$$S_n = S_n(C_n, TA_n;\ I_n).$$ [10]

This function recognizes that 'smoking' results from two inputs, cigarettes and time spent on the primary activity, plus intensity, which for simplicity we model as a technology parameter

[10] In contrast, Adda and Cornaglia (2010) model 'smoking time' as the sum of time spent at home, at work and at bars/restaurants (in the absence of bans). Smoking time and cigarettes smoked both enter the (separable) utility function, so there is no direct link between time and cigarettes; intensity is not considered.

that varies by activity. All three must be greater than zero for $S > 0$, but otherwise there are possible trade-offs and complementarities between the number of cigarettes smoked, time spent smoking and intensity. This smoking function varies across the different activities. Some activities are very difficult or impossible to combine with smoking, in which case the marginal productivity of TA is very low or zero. Likewise, some activities limit the possible intensity of smoking because of the exertion required (e.g., it is difficult to inhale cigarette smoke deeply).

The individual then chooses how to spend their time and monetary resources subject to a time constraint,

$$\sum TA_n = T,$$

and budget constraint,

$$wTA_N = p_c \sum C_n + p_M M + Y,$$

where T is total time available, w is the wage, and p_c and p_M denote the prices of cigarettes and medical inputs, respectively.

This simple framework reveals several mechanisms for smoking and physical exertion across different activities to be related to each other and affected by tobacco policy. First, as in Conway & Niles (2017), smoking and physical exertion could be viewed as either complements or substitutes in the production of ‘health,’ depending on whether H is overall health or weight management, respectively. Expanding on the ‘distaste’ effect they identify (that smoking may increase the disutility from exercise), the utility derived from each activity may be affected by the smoking that takes place during it (i.e., $U_{TA,S} \neq 0$). For instance, going for a walk or watching television may be more pleasurable while smoking. A new mechanism is that some activities facilitate smoking, and thus yield an additional benefit to consider for those wanting to smoke. For example, in deciding whether to go for a walk or a run, the individual considers not only the direct (dis)utility and marginal health benefits afforded by each but the ability to and benefits from smoking while doing so.

Cigarette costs can therefore also affect physical exertion through multiple channels. This framework is especially useful for considering the effects of other tobacco control policies such as smoking bans. In such cases, the production value of TA becomes zero – the time spent on an activity in a ‘banned’ environment (such as a smoke-free workplace) cannot be used for smoking.

This framework also suggests the additional mechanism of shifting away from that activity and reallocating time among the remaining activities towards those that better facilitate smoking. For example, a workplace ban may cause an individual to begin going on short walks during smoke breaks at work; conversely, outside of work they may run less and watch more television, either as a 'compensating health belief' and/or because television better facilitates smoking. Nguyen (2012) provides evidence of such a shift in smoking behavior, finding that smoking on weekends increases in response to workplace bans.[11]

Consider next an increase in cigarette taxes, which raises the price of cigarettes, p_c, and likely reduces smoking overall, thereby once again affecting exercise via the channels discussed in Conway and Niles (2017). However, it may also cause a reallocation across activities towards those that produce more 'smoking' with fewer cigarettes – those activities where more time is available to smoke or a greater intensity is allowed.

In sum, the main insight from this framework is that the time required to smoke suggests that cigarette costs and other tobacco-control policies likely affect physical exertion through multiple channels, including how easy it is to smoke during each activity. It also suggests that physical exertion may be affected even if overall smoking, as typically measured (number of cigarettes) does not appear to have changed, as the individual may have adjusted when or how intensely they smoke, which in turn could affect their level of activity.

IV. Empirical Methodology

The theoretical underpinnings which link smoking status and exercise or physical activity are complex, with reinforcing and counteracting pathways. Hence, the net impact on how individuals shift their exercise and activity patterns in response to a shift in smoking status is a priori indeterminate and becomes an empirical question. Our objective is to shed light on this relationship and empirically assess these effects of smoking status on recreational exercise and other forms of physical activity. Since we frame this question for adults, the primary distinction is between adults who have quit smoking relative to those who continue to engage in smoking. Focusing on quitting also simplifies interpretation because the *change* in 'smoking' is clearly measured (i.e., it has been reduced to zero) and should operate along the mechanisms identified

[11] As summarized in Nguyen (2012), previous studies have produced mixed evidence.

(makes certain activities more/less enjoyable and more/less ‘productive,’ and eliminates the ‘smoking time and intensity value’ of activities).

We take a two-pronged empirical approach. The first is a more structural approach in which we estimate: 1) the observed structural relationship between smoking and physical activity, and 2) the ‘first-stage’ effect of cigarette costs to investigate whether smoking behavior actually responds. This approach recognizes that for tobacco policy to affect physical activity, it must first affect smoking behavior and that smoking behavior must in turn affect physical activity, or $\partial TA/\partial p_c = \partial TA/\partial S$ (structural) x $\partial S/\partial p_c$ (first-stage). The second approach is the typical reduced form approach in which the net effect of tobacco policy on physical activity, $\partial TA/\partial p_c$, is estimated directly.

We specify the *structural demand function* for physical activity as:

$$TA_{ijdmt} = \beta_0 + \beta_1 S_{ijdmt} + X_{ijdmt}\,\Omega + \beta_2 E_{jmt} + \delta_j + \theta_d + \lambda_m + \eta_t + \varepsilon_{ijdmt} \qquad (1)$$

Exercise (or other types of physical activity, *TA*), for the i^{th} respondent residing in state *j* interviewed on day *d*, month *m*, and year *t*, is a function of smoking status *(S)*, measured as whether the individual has quit smoking, and a vector of exogenous personal characteristics *(X)*. All models also control for state indicators that capture unobserved time-invariant state-level heterogeneity (δ_j), as well as indicators for month (λ_m) and day of the week (θ_d). The latter capture unobserved seasonal factors and shifts in time constraints and the full cost of exercise and other activities across weekdays and weekends. The time period under study (2003-2012) also spanned strong positive and negative macroeconomic and labor market shocks, which prior research has shown to exert significant influence on individuals’ exercise and other time-use (Colman and Dave 2013; Ruhm 2005). Following these studies, we therefore include the one-month lag of the state employment-to-population ratio (E) to control for local-area labor demand, along with year indicators (η_t) to capture overall macroeconomic shocks and other unobserved national trends.

Equation (1) is estimated for various activities (TA), including measures of exercise, total non-work physical activity, as well as disaggregated activity categories (see Data section). All specifications are estimated with ordinary least squares (OLS), except where noted, and adjusted for the probability sampling weights provided by the ATUS. We assume that the error term (ε) is correlated across individuals in a given state and year, and therefore adjust standard errors for any arbitrary correlation within state-year cells.[12]

We restrict our analysis to persons 23 years old and above because we want to bypass the time when most smokers began smoking; our interest is in the effect of quitting smoking, rather than that of initiation. Data from the 2012 National Survey on Drug Use and Health indicate that virtually all smokers (95%) have initiated use by the age of 23. Due to inherent differences in time use, constraints, and activity patterns between males and females, all analyses are stratified across gender. We also estimate models for various subsets of the population, based on age and education, to assess heterogeneity in the effects of smoking status on activities. This heterogeneity may broadly stem from differential responses to tobacco control policy, which we assess below, and differences in individual-specific unobservables such as time and risk preference, health-related information, and health valuation, which to some extent would change over the person's life cycle and would also be associated with their educational attainment (Grossman 2000; Grossman and Kaestner 1997).

The parameter of interest is β_1, which estimates $\partial TA/\partial S$, the structural effect in terms of what happens to an individual's exercise or other activities upon quitting smoking, operating through any reinforcing and/or offsetting channels. The estimated effect, however, is potentially biased due to endogeneity concerns. First, smoking takes time, and to the extent that all time-use, and in particular time-use outside of one's work, is jointly determined, there may be simultaneity bias. The vast majority of smokers engage in smoking as a secondary activity (for instance, while watching TV or commuting), though approximately 10% of smokers in the ATUS report some primary time allocation, on the order of 23 minutes on average daily, to smoking. Second, there may be non-random selection on unobservable factors that may affect both the decision to quit smoking and to exercise (or partake in other physical activities). The bias due to this selection on unobservables may be positive or negative. For instance, on the one hand, a higher marginal valuation of health may induce an individual to both quit smoking as well as engage in other health-promoting behaviors such as exercise, imparting a positive bias to β_1. On the other hand, those with strong bodyweight concerns may engage in both smoking and greater exercise, which would

[12] A check of the residuals, conditional on state and time indicators, finds no intra-state correlation over time, which justifies our clustering by state and year.

impart a negative bias to β_1.[13] While we discuss estimates from equation (1) with the caveat that they may be biased due to these endogeneity concerns, they are useful in framing some of the baseline associations between smoking cessation and physical activity after conditioning on observable factors and state and time fixed effects.

As a next step, we address this potential endogeneity by exploiting plausibly exogenous variation in an individual's smoking status that is driven by changes in the price of a pack of cigarettes in their state of residence over time. A large literature has shown that prices matter significantly for smoking behaviors (see for instance, Cawley and Ruhm 2011; Chaloupka and Warner 2000). Especially salient for this study, recent evidence investigates behavioral mechanisms and finds that, for high-income countries such as the U.S., cigarette prices lower smoking primarily by promoting cessation (Kostova, Chaloupka, and Shang 2014). We explore if these smoking cessation effects exist for our sample by directly estimating the *first-stage response* to cigarette prices (*Price*), for males and females separately, as follows:

$$S_{ijdmt} = \alpha_0 + \alpha_1 \text{ Price}_{jmt} + X_{ijdmt}\, \Omega + \beta_2 \text{ E}_{jmt} + \alpha_j + \theta_d + \lambda_m + \eta_t + \mu_{ijdmt} \qquad (2)$$

Equation (2) represents a demand function for smoking cessation, which we estimate for adults who are either current smokers or have quit smoking (former smokers). The parameter α_1 provides an estimate for $\partial S/\partial p_c$. We exclude never smokers in estimating equation (2) for two reasons. First, given that the sample is limited to adults ages 23 and older, these never-smokers are unlikely to change their smoking status (that is, initiate into smoking) as a result of changes in prices.[14] Second, by excluding never-smokers, equation (2) helps to explicitly derive how cigarette prices impact the probability of quitting smoking among current and former smokers.

We capitalize on this link between prices and smoking cessation to obtain the *reduced-form effects* of cigarette prices on exercise and physical activity, by substituting (2) into (1), and estimating the following reduced-form specification:

---

[13] Smokers also subjectively report that cigarette smoking alleviates stress, though the effect may be transient and gender-dependent (Perkins et al. 1992). Exercise has also been found to have anti-depressant effects and a protective effect against adverse consequences of stress (Salmon 2001). Hence, unobserved stress levels may drive the decision to remain a current smoker while concurrently engaging in other stress-reducing activities such as exercise and physical activity, which would similarly impart a negative bias to β_1.

[14] We exploit the group of never-smokers as a falsification check later, which is consistent with this presumption.

$$TA_{ijdmt} = \pi_0 + \pi_1 \, Price_{jmt} + X_{ijdmt} \, \Omega + \pi_2 \, E_{jmt} + \alpha_j + \theta_d + \lambda_m + \eta_t + \upsilon_{ijdmt} \qquad (3)$$

The parameter of interest is π_1, which captures the net effect of cigarette price on physical activity through its impact on smoking status. Conditional on state and time fixed effects, in conjunction with other individual and state-specific observable characteristics, the state-level cigarette price is plausibly orthogonal to the individual-level unobservables (μ and υ) in both equations (2) and (3), and thus exogenous. We note that an extensive prior literature that has estimated smoking demand functions (versions of equation 2) or the effects of tobacco control policies on non-smoking outcomes such as obesity (versions of equation 3) has exploited similar variation for identifying causal effects.[15] With both reduced-form effects in hand - α_1 from equation (2), capturing the impact of prices on smoking cessation, and π_1 from equation (3), capturing the impact of prices on exercise/activities - we can further derive the suggestive causal structural effect of smoking cessation on exercise/activities (a crude consistent version of β_1) under some behavioral assumptions.[16]

While we present our main analyses based on the state-specific cigarette price, an alternative approach would have been to utilize the state-specific cigarette excise tax. We utilize prices mainly to maximize the within-state identifying variation and statistical power. As argued by Grossman, Chou, and Saffer (2006), the price is a better and more salient measure of the cost of cigarettes than the excise tax. Cigarette prices certainly vary due to differences in the tax rate, but they also vary due to other exogenous sources. In utilizing the excise tax, one discards important exogenous variation in cigarette prices due to variation in transportation and shipping costs, retailing and operation costs, and the degree of monopoly power of tobacco manufacturers across states. Furthermore, the tax-shifting behavior established in the literature, wherein a one-cent increase in the excise tax has been found to increase price by more than one-cent, along with evidence that the market-level demand-price elasticity is less than unity are consistent with the cigarette market operating under a form of imperfect competition.[17] Grossman, Chou, and Saffer

[15] All of the studies of the effects of tobacco policy on obesity and exercise cited earlier use such equations.

[16] We do not implement formal instrumental variables (IV)-based models since prices may also affect smoking at the intensive margin – that is, in addition to quitting, prices may reduce the number of cigarettes consumed among current smokers without changing smoking status. It is possible that a reduction in cigarettes consumed may impact exercise and other activities, even if the individual has not fully quit smoking.

[17] We are able to replicate both of these findings with the merged ATUS/CPS-TUS data.

(2006) show that this scenario is also consistent with the individual-level error term in equation (2) being uncorrelated with the cigarette price.

Finally, we implement a number of checks to indirectly assess the validity of the identifying assumption and the credibility of the estimated effects. First, we estimate equation (1) additionally controlling for the cigarette price. It is validating that price is statistically and economically insignificant in these models, suggesting that the effect of price on physical activity in equation (3) is driven solely by changes in smoking status.[18] Second, we assess dose-response effects. That is, if higher cigarette prices are having a causal impact on exercise and activity, then we would expect this impact to be stronger for those groups for whom the higher prices elicited a larger response in terms of smoking cessation. Third, we employ the sample of never-smokers in a placebo analysis. Given that these adults are older than the age at which virtually all smokers have initiated smoking, we do not expect to find any significant effects of cigarette prices on exercise or activities for this group. If we did find significant effects, then this finding would reflect spurious correlation and cast a specter of doubt on our identifying assumption that the cigarette prices are orthogonal to the error term. As we discuss later, it is indeed validating that we do not detect any significant effects among never-smokers, a group for whom theoretically there should be no strong effects.

V. Data

Our analyses are based on individual records from the American Time Use Surveys . The ATUS is the first federally administered survey of time use in the U.S. Begun in January, 2003, it is a monthly survey of the civilian non-institutional population of the U.S., 15 years and older. To avoid the confounding effects of the explosion in e-cigarette use, we end our analyses in December, 2012, at which time the data contained about 137,000 observations. Participants in the ATUS are selected from households that have completed their eighth interview as part of the Current Population Survey (CPS). Two to five months after the final CPS interview, one member of the

[18] We also implemented another indirect test of our identifying assumption, based on Wooldridge (2002). We estimated an IV-based version of equation (1), employing state-specific cigarette prices as an IV for smoking status, and regressed second-stage residuals from this model on the cigarette price. The coefficient of price was statistically insignificant and close-to-zero in magnitude, indicating that prices are plausibly uncorrelated with individual-level disturbances.

household 15 years or older is selected to report, minute by minute, on his or her activities on a day of the week chosen by the BLS. Half of the days selected for reporting are on the weekend, as people generally do more activities on the weekend than on weekdays. Eligible households with a Hispanic or non-Hispanic African-American householder are oversampled. Sampling weights are provided to account for the oversampling of Hispanics and African-Americans and of weekends. Unlike the BRFSS and the NHIS, which sample only telephone-based households, approximately 5% of the ATUS consists of CPS respondents that did not provide a telephone number in order to make the sample truly representative.

The time-diary component of the interview contains a detailed account of the respondent's activities, starting at 4 a.m. on the day selected by the BLS and ending at 4 a.m. the following morning. Each activity is assigned a six-digit classification code. The first two digits represent one of 17 major activity codes (ranging from personal care to household services to exercise and sports); the next two digits represent the second-tier level of detail, and the final two digits represent the third, most detailed level of activity. For example, the ATUS code for "Spelunking" is 130108, which is part of code 1301, "Participating in sports", which is part of code 13, "Sports, Exercise, & Recreation". If respondents report doing more than one activity at a time, they are asked to identify the primary activity. With the exception of when one activity is child care, the ATUS only records the primary activity. "Travelling" is a separate primary activity. For example, it is not counted as part of work unless the respondent's job inherently involves travelling, such as airline pilots.

Of the 137,000 respondents to the ATUS, we matched approximately 57,000 persons (41.4%) to valid responses in the TUS. Data from the TUS was used mainly to distinguish never-smokers from current and former smokers, as the behavior of the latter two groups would be most likely to respond to changes in the cost of cigarettes. Because the Census Bureau chooses the months and years in which to administer a Tobacco Use Supplement independently of the characteristics of the CPS respondents, the TUS subset of the ATUS data should be a random subset. Inspection of columns 2 and 3 of Table 1 confirms this presumption. The means in column 2, showing the whole ATUS sample, and column 3, the TUS subsample, are very similar for every variable. The means shown in Table 1, as well as regressions discussed later, are all weighted by the ATUS sampling weights. This is necessary because our main dependent variable, exercise, occurs mainly on the weekend, a part of the week that is oversampled.

Table 1: Weighted Means, American Time Use Surveys (ATUS) 2003-2012

Sample	**ATUS Ages 23+**	**ATUS/CPS-TUS Merged Sub-sample Ages 23+**	**ATUS/CPS-TUS & ATUS Ages 23+ Males**	**ATUS/CPS-TUS & ATUS Ages 23+ Females**
Current smoker	_	0.1597	0.1753	0.1455
Former smoker	_	0.2163	0.2537	0.1823
Never smoker	_	0.6241	0.5710	0.6722
Total physical activity (MET-adjusted minutes)	2280.7	2285.3	2345.9	2220.0
Total non-work physical activity (MET-adjusted minutes)	1774.3	1785.2	1702.5	1841.2
Total work physical activity	506.4	500.0	643.4	378.8
Any recreational exercise	0.1679	0.1696	0.1821	0.1547
Exercise (minutes)	15.4	15.4	19.8	11.3
Exercise (MET-adjusted minutes)	71.2	71.0	91.2	52.6
Sleeping	507.8	505.6	502.5	512.8
Personal care	94.9	95.1	78.9	109.9
Housework	303.3	315.1	246.5	356.1
Childcare	75.4	73.9	50.4	98.7
Adult-care	18.8	19.2	20.1	17.6
Education	14.5	12.9	12.6	16.2
Purchasing goods & services	61.7	62.3	48.0	74.5
Eating/drinking	103.1	104.6	107.0	99.4
Television	221.4	217.7	242.0	202.1
Socializing & relaxing	171.8	176.1	166.6	176.5
Other activities	168.7	169.5	174.0	163.7
Any smoking as a primary activity	0.0193	0.0175	0.0219	0.0168
Time spent smoking (smoking as a primary activity > 0)	24.4	23.0	26.5	21.9
Age	48.1	49.4	47.4	48.8
Hispanic	0.1230	0.1159	0.1304	0.1162
Non-Hispanic White	0.7141	0.7350	0.7166	0.7117
Non-Hispanic Black	0.1119	0.1025	0.1026	0.1206
Non-Hispanic other race	0.0510	0.0466	0.0504	0.0515
Married	0.6217	0.6409	0.6505	0.5948
Highest educational attainment: Less than high school	0.1241	0.1209	0.1298	0.1187
Highest educational attainment: High school graduate	0.3193	0.3135	0.3222	0.3166
Highest educational attainment: Some college	0.2519	0.2534	0.2378	0.2650
Highest educational attainment: College or above	0.3047	0.3122	0.3101	0.2997
Any own children < 18 years of age in household	0.3310	0.3274	0.3156	0.3453
State cigarette price ($ per pack)	4.83	4.77	4.84	4.83
State employment to population ratio (percentage points)	61.21	61.40	61.23	61.19
Observations	116,452	50,241	50,413	66,129

Notes: Weighted means are reported. All samples are restricted to respondents who report time-use for at least 23 hours on the diary data, approximately 93.94% of all respondents. Observations reported represent the maximum sample sizes. Sample sizes for a few variables are slightly lower due to missing information. For the last two columns, for males and females separately, the means are reported from the full ATUS sample for all variables except for the smoking history variables (the first 3 listed) which require the linked ATUS/CPS-TUS.

Another possible concern is time lapse between the report of smoking in the TUS and the report of exercise in the subsequent ATUS. On average, the ATUS interview occurs about 10 months after the TUS interview. This should not affect our estimates of the effect of prices and taxes on exercise since prices, taxes, smoking, and exercise behavior are highly correlated with their previous values over such a brief span of time. Any potential misclassification due to a change in smoking status over this period would attenuate our main effects, in which case the estimates can be interpreted as a conservative lower bound, ceteris paribus.

We combine information on the type of activity and its duration to construct a standardized and consistent measure of physical activity based on the metabolic equivalent of task (MET). A unit of MET is defined as the ratio of a person's working metabolic rate relative to their resting metabolic rate. For instance, one MET is defined as the energy it takes to sit quietly, and walking has a MET of 2. For the average adult, one MET represents about one calorie per every 2.2 pounds of bodyweight per hour. Estimates of the MET of over 600 activities are assembled in the Compendium of Physical Activities by Ainsworth et al. (2011), which are then matched to those in the ATUS based on Tudor-Locke, Washington, Ainsworth, and Troiano (2009). As our measure of exertion, we multiply the MET values for each ATUS activity by the number of minutes that the respondent spent on that activity. We term the resulting variable the "MET-adjusted" activity or MET-adjusted minutes, which reflects both the duration and intensity of each activity. For the occupational categories specified in the ATUS, Tudor-Locke (2009) estimates the average MET values based on the Tecumseh Occupational Physical Activity Questionnaire classification system, which describes the physical demands of over 500 census occupations.

Our primary outcomes are any engagement in recreational exercise, the number of minutes spent exercising and the exercise minutes multiplied by the MET value for each component activity within exercise. We also analyze MET-adjusted total minutes, which is the intensity of all physical activity or physical exertion undertaken during the day outside of work. Additionally, we examine disaggregated measures of physical exertion across the following sub-categories: sleeping, personal care, housework, childcare, adult-care, education, purchasing goods and services, eating and drinking, socializing and relaxing, and other activities.

Our main independent variable is the average cigarette price in the state where the respondent lived during the ATUS interview. Data on cigarette prices are nominal and are taken from The Tax Burden on Tobacco 2012, produced by Orzechowski and Walker.[19] Other independent variables include the one-month-lagged employment-to-population ratio in the month prior to the diary date in the state where the respondent lives (obtained from the Bureau of Labor Statistics Local Area Unemployment series), indicators for gender, education (less-than-high school, high school, some college, and college and above), marital status (married versus divorced/separated, widowed, never-married), race and ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic other race, and Hispanic), age, and the presence of children under the age of 18.

Not all respondents described their activities in sufficient detail for the ATUS coders to assign an activity code to every minute of the respondent's diary day. The most common reasons for gaps in the time diary are that the respondent's description of their activity during a particular minute is too vague to categorize, or the respondent cannot remember what they were doing in that minute. We restrict our analyses to observations for which the total minutes reported is at least 1380 minutes, that is 23 out of 24 hours, a sample that includes 94% of possible observations, and include in each specification the log of the respondent’s total accounted time on the diary day.

Table 1 presents the weighted means for the full ATUS sample and the merged ATUS/CPS-TUS subsample, and separately for males and females. This table reveals that men report more physical activity overall and especially at work and in recreational exercise. However, women report more non-work physical activity (other than exercise) and in particular report more MET-adjusted minutes in all other categories except for adult care, eating/drinking, watching television and ‘other’. Data from the linked ATUS/CPS-TUS subsample show that women also are more likely to report never having smoked (67% vs. 57%) but a smaller gap exists between current and former smokers. These statistics underscore the value of stratifying by gender and the importance of considering other kinds of physical activity besides formal exercise.

VI. Results

Following the empirical methodology set out in section IV, we estimate *first stage* (effects of cigarette prices on smoking), *structural form* (effects of smoking on physical activity) and *reduced form* (effects of cigarette taxes on physical activity) models. The first two types require

[19] Time fixed effects account for national changes in the general price level (inflation).

the smaller, CPS-TUS subsample unless otherwise noted, whereas the reduced form can use the full ATUS sample. Taken together, these results identify the mechanisms through which tobacco policy and smoking affect physical activity.

A. First-Stage Effects – The Effect of Cigarette Prices on Smoking

We assess the strength of the first-stage effects of cigarette price on smoking in Table 2, based on equation (2). Results for males are presented in Panel A. These models utilize information on smoking status from the CPS-TUS that has been merged to the ATUS. The outcome is an indicator for having quit smoking, and the sample is limited to current and former smokers. Across all of these models, cigarette price is significantly and positively associated with smoking cessation. Specifically, among adult males ages 23 and older, a $1 increase in the price per pack raises the probability of smoking cessation by 4.2 percentage points; the cessation-price elasticity is estimated at 0.48.[20] Given that tobacco-related morbidity is a significant cause of premature death, mortality among current or former smokers may lead to a progressively selected sample by including individuals at older ages. Hence, the next specification excludes males above the age of 69 in order to minimize such survival-based selection; the elasticity magnitude remains robust at 0.45.[21] We also find that older smokers (ages 46-69) are substantially more likely to quit relative to younger smokers (ages 23-45) when prices rise; the cessation elasticity for older smokers is 0.63, about twice as large as for younger smokers. Columns 5 and 6 indicate differential responses based on education and suggest a stronger response among higher-educated respondents relative to those who are high school graduates or below (elasticity of 0.66 vs. 0.37). Our results therefore confirm that, for our study sample of males, cigarette prices exert a strong and significant influence on the likelihood of cessation. Hence, variation in cigarette prices provides a strong exogenous shock to smoking cessation among males, which we exploit to infer the causal effects of smoking cessation on physical activity.[22]

[20] Our price elasticity of cessation is in line with recent estimates (see for instance, Kostova et al. 2014).

[21] Estimates are also robust to restricting the sample to ages 23-59.

[22] We also estimated models that utilize smoking information directly from the ATUS; specifically, individuals report on their primary time spent using tobacco on a given diary day. Only about 10% of smokers report any time spent using tobacco as most of them engage in smoking as a secondary activity, while performing some other primary activity. Moreover, the ATUS also does not distinguish between time spent using tobacco and time spent using drugs,

Table 2: Effects of Cigarette Cost on Smoking Cessation, CPS-TUS 2003-2012

	Panel A: Males					
	Ages 23+	**Ages 23-69**	**Ages 23-45**	**Ages 46-69**	**Low Educated**	**High Educated**
Cigarette Price	0.0419***	0.0447***	0.0391**	0.0506***	0.0431**	0.0529***
	(0.0105)	(0.0121)	(0.0197)	(0.0169)	(0.0175)	(0.0184)
Elasticity	ε = 0.484	ε = 0.453	ε = 0.312	ε = 0.631	ε = 0.368	ε = 0.657
Observations	9,475	7,954	3,237	4,717	3,588	4,366
	Panel B: Females					
	Ages 23+	**Ages 23-69**	**Ages 23-45**	**Ages 46-69**	**Low Educated**	**High Educated**
Cigarette Price	-0.0203	-0.0179	0.0012	-0.0305	-0.0129	-0.0250
	(0.0147)	(0.0169)	(0.0233)	(0.0199)	(0.0282)	(0.0174)
Elasticity	ε =-0.216	ε =-0.175	ε = 0.009	ε = -0.350	ε = -0.102	ε = -0.304
Observations	9,688	8,194	3,635	4,559	3,349	4,845

Notes: Coefficients are reported. Standard errors, reported in parentheses, are adjusted for arbitrary correlation within state-year cells. All models adjust for sampling weights, control for state and period fixed effects (year, month, day), and control for age, age-squared, Hispanic, non-Hispanic black, non-Hispanic other race, high-school graduate, some college, college or above, any own minor children in the household, natural log of total reported time on the diary day, state employment-to-population ratio, and interactions between race/ethnicity and educational attainment. Sample is restricted to respondents who report on at least 23 hours of time use on the diary day. Asterisks denote significance as follows: *** p-value≤0.01; **0.01<p-value≤0.05; *0.05<p-value≤0.10.

The lower panel presents parallel estimates for females, and in complete contrast to males, finds no evidence that higher cigarette costs are associated with greater smoking cessation. Several clinical studies of smoking interventions uncover gender differences such that women are found to be less likely to successfully abstain from smoking relative to men, though such differences are less pronounced in more representative population-based studies (Jarvis et al. 2012; Perkins and Scott 2008; Bohadana et al. 2003). For our study sample, the quit rate among male smokers is

and combines both in a single time-use category. We find that higher cigarette costs reduce total primary time spent smoking, with a larger estimated elasticity for males (-2.04) relative to females (-0.76); these estimates are marginally significant at the 10% level. These estimates should be interpreted with caution given the measurement issues. We also note that the reduction in primary time spent smoking may partly reflect a greater shift towards engaging in smoking as a secondary activity; nevertheless, this reduction is also consistent and likely to be, at least partly, driven by an increase in smoking cessation.

about 59.1% compared with 55.6% among females.[23] Given that smoking cessation among female smokers is non-responsive to the price of cigarettes in our study sample, and the ensuing weak identifying variation, we interpret our results for females as suggestive associations and do not press a causal interpretation as we are able to do for males.[24]

B. Structural and Reduced Form Models of 'Exercise'

Table 3 reports results for the likelihood of engaging in recreational exercise separately for males and females. Panel A presents estimates of the (structural) effects of smoking status, based on equation (1). These models consistently suggest that, relative to current smokers, males who have quit are significantly more likely to exercise.[25] Specifically, males who have quit have a higher probability of actively exercising, on the order of about 4 percentage points, relative to those who continue to smoke. This response is significantly larger among older males (ages 46-69) and among those who are higher-educated. While these estimates are suggestive of smoking cessation leading to other health-promoting investments such as exercise, they are potentially biased due to the endogeneity concerns discussed earlier.

---

[23] Some of the suggested reasons for a lower successful quit rate among females relate to differences in the way that women respond to nicotine, a greater reliance on smoking as a coping mechanism among women, or a higher emphasis on bodyweight management. Some research also suggests that, compared with female hardcore smokers, male hardcore smokers are more likely to face smoking restrictions at work (Augustson et al. 2008). If this leads to more male smokers being on the margin of smoking vs. quitting, then it is plausible that higher prices would elicit a stronger cessation response among males.

[24] It is also possible that the price elasticity of smoking may have declined in recent periods, and particularly for females. For instance, Callison and Kaestner (2014), in analyzing TUS data that span recent periods up to 2007, generally find much weaker negative tax elasticity estimates overall, about 0.05 or less, in comparison with older studies. Conway and Niles (2017) similarly find much weaker effects of cigarette taxes on both smoking and exercise in their 2001-2012 subsample than for the pre-2001 period. Assuming that state excise taxes comprise 25% of the cigarette price (approximate proportion over our sample period), and that the pass-through of cigarette taxes to prices is about 1 to 1.1 (DeCicca et al. 2010; Sumner 1981), a tax elasticity of -0.05 would translate into a price elasticity of about -0.20. While Callison and Kaestner (2014) do not separate the effects across gender, their overall price elasticity estimate is also consistent with a weighted average of the elasticity estimates we find for males and females, as well as the elasticity estimate we obtain when we pool both genders (-0.16 to -0.21).

[25] The similar holds true for never-smokers, and excluding never-smokers from the analysis does not materially change the relative effects for former-smokers versus current-smokers.

Table 3: Effects of Smoking Status and Cigarette Cost on Any Recreational Exercise, ATUS / CPS-TUS 2003-2012

Sample	**Males**						**Females**					
	Ages 23+	**Ages 23-69**	**Ages 23-45**	**Ages 46-69**	**Low Educ.**	**High Educ.**	**Ages 23+**	**Ages 23-69**	**Ages 23-45**	**Ages 46-69**	**Low Educ.**	**High Educ.**
Panel A: Effects of Smoking Status – Structural Estimates												
Former Smoker	0.0438***	0.0417***	0.0236	0.0542***	0.0209	0.0603***	0.0456***	0.0473***	0.0469***	0.0521***	0.0219	0.0732***
	(0.0097)	(0.0100)	(0.0165)	(0.0132)	(0.0140)	(0.0147)	(0.0103)	(0.0115)	(0.0166)	(0.0147)	(0.0160)	(0.0158)
Never Smoker	0.0504***	0.0501***	0.0450***	0.0522***	0.0452***	0.0578***	0.0582***	0.0593***	0.0444***	0.0720***	0.0351***	0.0851***
	(0.0078)	(0.0084)	(0.0129)	(0.0121)	(0.0126)	(0.0112)	(0.0083)	(0.0088)	(0.0126)	(0.0112)	(0.0113)	(0.0124)
Observations	21,509	18,900	9,509	9,391	6,942	11,958	28,732	24,129	12,528	11,601	8,454	15,675
Panel B: Effects of Cigarette Cost – Reduced Form Estimates												
Cigarette Price	0.0124***	0.0144***	0.0090	0.0196**	0.0168*	0.0137**	-0.0043	-0.0036	-0.0032	-0.0053	0.0002	-0.0055
	(0.0047)	(0.0048)	(0.0079)	(0.0089)	(0.0097)	(0.0068)	(0.0048)	(0.0052)	(0.0072)	(0.0067)	(0.0062)	(0.0070)
	[ε=0.329]	[ε=0.388]	[ε=0.242]	[ε=0.524]	[ε=0.584]	[ε=0.314]	[ε=-0.134]	[ε=-0.112]	[ε=-0.099]	[ε=-0.167]	[ε=0.009]	[ε=-0.143]
Observations	50,413	44,944	23,947	20,997	16,946	27,998	66,129	56,528	30,732	25,796	20,404	36,124
Panel C: Implied Structural Effect of Smoking Cessation												
First-stage Elasticity[1]	ε=0.484	ε=0.453	ε=0.312	ε=0.631	ε=0.368	ε=0.657	ε=-0.216	ε=-0.175	ε=0.009	ε=-0.350	ε=-0.102	ε=-0.304
Implied Structural Elasticity of Smoking Cessation[2]	ε=0.679	ε=0.857	ε=0.776	ε=0.830	ε=1.586	ε=0.478	_	_	_	_	_	_

Notes: Structural effects of smoking status on recreational exercise (Panel A) are based on the CPS-TUS subsample. Reduced-form effects of cigarette cost on recreational exercise (Panel B) are based on the full ATUS. See remaining notes for Table 2. Elasticity (ε) of outcome with respect to cigarette price is reported for the reduced-form models (Panel B) in square brackets.

[1] Cigarette demand-price elasticity for current smoking participation from Table 2 is reported.

[2] Implied structural elasticity is the ratio of the elasticity of exercise with respect to price over the first-stage cessation-price elasticity. See text.

Panel B therefore exploits the strong connection between cigarette costs and smoking cessation among males (as established in Table 2 Panel A) to identify the causal link, based on equation (3). Because no smoking data are required, these reduced-form models are estimated on the broader ATUS sample. All of the estimated coefficients of cigarette price are positive, which is consistent with the estimates from Panel A. Higher cigarette prices are associated with a higher probability of exercising by promoting smoking cessation. The exercise-participation elasticity with respect to price ranges from 0.24 to 0.58, with a higher response found among older males (elasticity of 0.52 versus 0.24 for younger males) and among those who are low-educated (0.58 versus 0.31 for higher-educated males).[26]

We can combine these reduced-form exercise-price elasticity estimates with the first-stage cessation-price elasticity estimates (from Table 2) to back-out an implied structural elasticity of exercise with respect to smoking cessation.[27] These are reported next (in Panel C), and range in magnitude from 0.48 to 1.59. As with the price response, the behavioral response is somewhat stronger among older males. We also find a substantially stronger behavioral response in exercise among those who are lower-educated, despite the fact that their smoking cessation is somewhat less responsive to price. [It should be noted that the prevalence of exercise (smoking) among low-educated smokers is relatively low (high); hence, equal size changes in smoking and exercise would translate into a larger relative effect.] Both effects may also reflect the fact that more low-

[26] The effects of the other covariates are generally consistent with expectations and prior studies (Conway and Niles 2017; Colman and Dave 2013; Saffer et al. 2013; Humphreys and Ruseski 2011). Exercise tends to increase with age. We do not find differences among males across race/ethnicity or marital status. However, Hispanic and non-Hispanic black females (relative to non-Hispanic whites) and married females are significantly more likely to exercise. For both genders, higher educational attainment is associated with a significantly higher probability of engaging in exercise, consistent with a large literature suggesting that educated individuals may be more allocatively-efficient in health production and thus more likely to engage in healthy behaviors (Grossman and Kaestner 1997). Presence of minor children in the household is associated with a lower likelihood of exercising for both males and females, consistent with an increase in time constraints. Weaker economic conditions, as proxied by the state employment-to-population ratio, are generally associated with an increase in exercise, which is consistent with the findings from Colman and Dave (2013). Expectedly, exercise participation also displays a strong seasonal pattern, increasing monotonically over the year until the summer months and then declining.

[27] This is similar to a Wald estimate for the IV effect of smoking cessation on exercise, using exogenous identifying variation in cigarette prices.

educated smokers tend to be hardcore smokers, and with a higher addictive stock, their smoking behaviors would be expected to be less price-responsive.[28] Furthermore, given that low-educated smokers smoke more, upon cessation they are likely to experience a greater relative improvement in lung function and other health benefits. Thus, the physical cost of exercising would decline more for a low-educated smoker who quits, making it more likely that they would engage in active exercise relative to a high-educated former smoker, ceteris paribus.[29] This suggests that higher cigarette prices may be doubly health-promoting for a vulnerable population that tends to engage in more smoking and less exercise to begin with and is at a greater risk of being overweight or obese.[30]

These structural estimates are meant to be only suggestive and should be interpreted with caution for at least two reasons. First, estimates rescaled in this way can differ substantially with relatively small changes in the underlying estimates. Second, the structural elasticities are likely overstated because they are constructed under the presumption that cigarette prices impact exercise only through a cessation pathway. However, higher prices also affect smoking at the intensive margin – reducing the number of cigarettes consumed or increasing the intensity with which each cigarette is smoked (Adda and Cornaglia 2006; Chaloupka and Warner 2000) even if the smoker does not change smoking status – which in turn may have second-order effects on exercise and other activities. Nevertheless, even if the magnitudes may be overstated, these considerations do not affect the sign of the structural estimates. These estimates show with a degree of confidence that smoking cessation plays a causal role in increasing engagement in recreational exercise.

Turning to corresponding estimates for females, we find that quitting smoking is consistently associated with a significantly higher probability of exercise participation, with coefficient magnitudes that are largely similar to those for males. Given that female smokers are not responsive to cigarette prices in terms of quitting smoking, there is inadequate identifying

[28] About 76% of high-educated smokers are everyday smokers, compared with 84% of low-educated smokers.

[29] Analogously, low-educated smokers who quit may also be somewhat more vulnerable to weight gain, and this may impact their decision to exercise, conditional on their marginal valuation of health and bodyweight.

[30] Only 14% of low-educated males engage in recreational exercise, compared with 22% of high-educated males.

variation and we therefore do not emphasize the results for cigarette prices except to note that, consistent with Table 2, no statistically significant reduced-form relationship exists (Panel B).[31]

Table 4 presents these same estimates for measures of exercise duration. The results for males follow the same pattern as noted for exercise participation (Table 3). Looking at total minutes of exercise engagement on the diary day, males who have quit smoking exercise more, by about 5 minutes daily, relative to current smokers (Panel A).[32] This positive association holds in the reduced form models (Panel B) – higher cigarette prices lead to greater exercise duration. The implied structural effect of total exercise minutes with respect to smoking cessation is therefore positive, with an implied elasticity of 0.48.[33] Since the effect on total exercise minutes conflates effects at both the extensive margin (decision to engage in any exercise) and the intensive margin (duration of exercise, conditional on engagement), both of which may respond differently (Humphreys and Ruseski 2011), we also estimate models separately for the intensive margin (total exercise minutes for individuals who report positive recreational exercise). Compared to the results in Table 3 which had pointed to significant and strong effects at the extensive margin for males, we do not find any significant causal effects of smoking cessation on the duration of exercise among those who were already exercising.

Similar to males and consistent with the structural form estimates in Table 3, we find that being a former smoker is associated with about a 3-minute increase in daily exercise among

[31] The associations between smoking cessation and exercise for females (Panel A) are very similar to those for males, both in terms of the direction of effect and the general pattern across groups. Utilizing exogenous price-based variation does not change the direction of the effects for males. Therefore, under the assumption that the degree of unobserved selection is similar between males and females, it is likely that at least part of the observed positive association represents a causal link and therefore smoking cessation would also lead females to engage more in recreational exercise.

[32] We note that this increase in exercise minutes, experienced by those who quit smoking, is greater than the decrease in the primary time spent on smoking (models reported in footnote 22). This suggests that the increase in exercise is not simply due to an easing of time constraints (reallocation of the time saved from not smoking towards more exercise), but also reflective of other channels which promote exercise, for instance a reduction in the physical cost of engaging in exercise or a greater marginal return from health investments.

[33] Patterns across subgroups are highly similar to those presented in Table 3, with larger responses estimated for older adults and for those with lower educational attainment.

females, with almost all of this effect occurring at the extensive margin. As expected, we again find no effects in the reduced form models.

Table 4: Effects of Smoking Status and Cigarette Cost on Exercise Minutes, ATUS / CPS-TUS 2003-2012

Sample	**Males Ages 23+**			**Females Ages 23+**		
Outcome	**Total Exercise Minutes**	**Total Exercise Minutes (Exercise>0)**	**Total MET-Adjusted Exercise Minutes**	**Total Exercise Minutes**	**Total Exercise Minutes (Exercise>0)**	**Total MET-Adjusted Exercise Minutes**
	Panel A: Effects of Smoking Status – Structural Estimates					
Former Smoker	4.6222***	5.9715	22.5420***	2.5976***	-3.9593	14.6217***
	(1.0564)	(4.9967)	(4.9894)	(0.7633)	(3.9750)	(3.6037)
Never Smoker	4.3178***	-1.4389	23.0344***	3.8301***	-1.7662	19.8801***
	(0.8209)	(4.2880)	(3.8079)	(0.7076)	(3.7307)	(3.3378)
Observations	21,509	4,038	21,509	28,732	4,252	28,732
	Panel B: Effects of Cigarette Cost – Reduced Form Estimates					
Cigarette Price	0.9515*	-2.3205	4.6882*	-0.2574	0.1135	-0.8188
	(0.5185)	(1.8146)	(2.7587)	(0.3561)	(1.8392)	(1.8119)
	[ε=0.233]	[ε=-0.105]	[ε=0.249]	[ε=-0.109]	[ε=0.008]	[ε=-0.075]
Observations	50,413	9,301	50,413	66,129	9,554	66,129
Implied Structural Elasticity of Smoking Cessation[1]	ε=0.481	_	ε=0.514	_	_	_

Notes: See notes for Table 3. All models also control for an indicator for respondents who reported exercising for more than 4.5 hours (about 0.88% of all respondents) on the diary day to minimize the influence of these outliers. Elasticity (ε) of outcome with respect to cigarette price is reported in square brackets.
[1] Implied structural elasticity is the ratio of the elasticity of exercise with respect to price over the first-stage cessation-price elasticity. See text.

In Table 4, we report estimates for a precise measure of recreational exercise, which captures both the duration as well as the intensity of the component activities as reflected in the MET value. The results for both males and females follow the same patterns as discussed above. Among males, smoking cessation is associated with greater exercise on the order of about 22 MET-adjusted minutes daily, and this positive association is plausibly causal as the results are consistent when utilizing exogenous cigarette price-based variation.[34] Among females, we continue to find a significant positive association between quitting smoking and exercise, though the magnitude is somewhat smaller (an increase in 15 MET-adjusted minutes) relative to males, which is again similar to the pattern of results discussed with respect to exercise duration (total exercise minutes). Finally, it should be noted that, as with exercise duration, these effects are mostly driven by shifts at the extensive margin.

C. Broader Measures of Physical Activity and Robustness Checks

Next, we assess broader measures of physical exertion, which capture all forms of physical activity. Table 5 reports estimates from models for all non-work physical activity, measured in MET-adjusted minutes that account for both the duration and intensity of the activities. Based on the structural estimates in Panel A, for men, never smokers perform less non-work physical activity overall than current or former smokers (who behave similarly). This finding therefore suggests that the greater exercise observed among never smokers is more than offset by reduced physical exertion in other activities, but the same cannot be said for former smokers. For women, never smokers and former smokers behave similarly; both exercise more but perform less of other types of physical activity such that the net effect on non-work physical activity is not significantly different from zero. In sum, the increased exercise among never or former smokers is offset – and perhaps more than offset – by a decline in other forms of non-work physical exertion.[35]

The reduced form results (Panel B) reveal no consistent effect of cigarette prices on these other forms of activity for men, although a large, almost statistically significant *positive* effect

[34] In supplementary models, we further find that the increase in exercise is mostly coming from an increase in low-MET activities (defined as activities with a MET value of 4 or below) rather than an increase in high-MET activities. This is reasonable in that males induced by higher cigarette prices to quit smoking appear to be exercising more by engaging in relatively low-intensity activities such as biking or walking. It would have been implausible to see any large-scale substitution from little or no exercise to engagement in relatively high-intensity activities such as jogging or hiking in the short-term subsequent to smoking cessation.

[35] These estimates may also reflect occupational sorting across current, former, and never smokers, and thus should be interpreted with caution. The reduced form estimates (Panel B), linking more exogenous variation in cigarette costs to activities arguably address this endogenous sorting.

Table 5: Effects of Smoking Status and Cigarette Price on Total Non-Work MET-adjusted Minutes, ATUS / CPS-TUS 2003-2012

Sample	**Males**						**Females**					
	Ages 23+	**Ages 23-69**	**Ages 23-45**	**Ages 46-69**	**Low Educ.**	**High Educ.**	**Ages 23+**	**Ages 23-69**	**Ages 23-45**	**Ages 46-69**	**Low Educ.**	**High Educ.**
	Panel A: Effects of Smoking Status – Structural Estimates											
Former Smoker	9.8087	2.5752	19.8170	-23.4479	-27.6479	40.0224	-10.3037	-10.3712	10.6214	-25.8311	-28.3366	1.9413
	(14.9989)	(16.0709)	(23.7847)	(22.6394)	(21.8090)	(25.0852)	(13.7008)	(14.9756)	(21.2439)	(19.8455)	(22.1838)	(19.7322)
Never Smoker	-34.1362**	-29.9457**	-5.2246	-60.5099***	-53.0153***	2.9960	-7.4248	-0.8632	17.1710	-19.1940	-11.1064	8.7414
	(13.3281)	(14.4451)	(18.4378)	(20.7111)	(20.4962)	(21.1465)	(11.6022)	(12.5581)	(18.5143)	(17.8688)	(16.6414)	(16.9930)
Observations	21,509	18,900	9,509	9,391	6,942	11,958	28,732	24,129	12,528	11,601	8,454	15,675
	Panel B: Effects of Cigarette Cost – Reduced Form Estimates											
Cigarette Price	-1.4409	1.1086	4.8856	-2.4611	17.8975	-9.9345	-7.8755	-8.2284	-19.6951*	4.2817	-15.5996	-4.0533
	(8.1486)	(8.2868)	(11.0843)	(11.0627)	(15.7528)	(9.2391)	(6.1372)	(7.0327)	(11.0157)	(8.2982)	(14.0136)	(10.7892)
	[ε=-0.004]	[ε=0.003]	[ε=0.014]	[ε=-0.007]	[ε=0.051]	[ε=-0.029]	[ε=-0.021]	[ε=-0.022]	[ε=-0.052]	[ε=0.011]	[ε=-0.040]	[ε=-0.011]
Observations	50,413	44,944	23,947	20,997	16,946	27,998	66,129	56,528	30,732	25,796	20,404	36,124

Notes: See notes for Table 3. Elasticity (ε) of outcome with respect to cigarette price is reported for the reduced form models in square brackets.

exists for low educated men. This result is intriguing because it suggests that higher cigarette prices may increase exercise *as well as* other forms of non-work physical activity for this vulnerable group. For women there is weak evidence of a negative effect that is roughly consistent with those of the structural estimates

We explore other margins for adjustment further in Table 6, where we model changes in disaggregated activity categories, each measured in MET-adjusted minutes and accounting for both the duration and intensity of all activity components. Panel A presents evidence for males. While the estimates based on actual smoking cessation are far more precise, those based on cigarette prices are less so as we lose some identifying variation when considering these disaggregated measures. Generally, both sets of estimates (structural and reduced form), however, are consistent in terms of the direction of the effect. Broadly, these estimates suggest that while smoking cessation is associated with an increase in exercise engagement, it is also associated with a decrease in sleep, housework, and television watching, and an increase in personal care, purchasing goods and services, socializing and relaxing, and other activities. We note that in some cases exogenously-driven smoking cessation is associated with a decrease in relatively intensive activities (for instance, housework), in some cases an increase (for instance, exercise, purchasing goods & services), and in other cases, an increase in less-intensive activities (socializing/relaxing) as well as a decrease in some sedentary activities (watching television). Hence, these findings are consistent with those from Table 6 in that the net effect on overall, non-work physical activity is small.

Patterns for females (Panel B) are generally the same with a few notable differences. First, the declines in sleep and television watching appear to be larger among males, whereas the decline in housework appears to be much larger among females. Second, smoking cessation among females is also associated with an increase in childcare; this is consistent with family reasons and children being a strong impetus for women to quit smoking. Third, smoking cessation is associated with a larger decline in socializing and relaxing relative to males.

Our final analyses, reported in Table 7, indirectly test the validity of our research design and our identifying assumption by estimating the same models for a sub-population for whom we would not expect any strong behavioral responses to cigarette costs – namely, unmarried male

Table 6: Effects of Smoking Status and Cigarette Price on Total MET-adjusted Minutes in Other Activities, ATUS / CPS-TUS 2003-2012

	Panel A: Males Ages 23-69										
Outcome	Sleeping	Personal Care	Housework	Childcare	Adult-care	Education	Purchasing Goods & Services	Eating & Drinking	Television	Socializing & Relaxing	Other
	Effects of Smoking Status – Structural Estimates										
Former Smoker	-10.3703**	7.8146*	-26.9202**	0.1562	1.6899	0.0567	11.0955***	6.0372**	-38.4062***	-9.1371	30.3563***
	(4.4570)	(3.9936)	(11.7907)	(3.5360)	(3.7722)	(3.5319)	(2.9409)	(2.3629)	(6.4498)	(6.4433)	(5.6752)
Never Smoker	-10.3001***	8.3937***	-28.1758***	-5.3958	3.3339	0.7494	5.4728**	3.6194*	-43.7811***	-21.7758***	32.5719***
	(3.7614)	(3.1783)	(9.3614)	(3.4216)	(3.4541)	(4.0287)	(2.3083)	(2.1655)	(6.1483)	(6.1763)	(4.5203)
Observations	18,900	18,900	18,900	18,900	18,900	18,900	18,900	18,900	18,900	18,900	18,900
	Effects of Cigarette Cost – Reduced Form Estimates										
Cigarette Price	-0.5626	0.9579	-4.4452	-1.7283	-1.7252	-0.6800	2.8472**	-0.3519	-3.8703	7.0093**	3.6747
	(1.9062)	(1.0768)	(4.6157)	(1.7170)	(1.4344)	(1.8395)	(1.2654)	(1.0868)	(2.4346)	(2.8615)	(2.4639)
Observations	44,944	44,944	44,944	44,944	44,944	44,944	44,944	44,944	44,944	44,944	44,944
	Panel B: Females Ages 23-69										
Outcome	Sleeping	Personal Care	Housework	Childcare	Adult-care	Education	Purchasing Goods & Services	Eating & Drinking	Television	Socializing & Relaxing	Other
	Effects of Smoking Status – Structural Estimates										
Former Smoker	-0.5891	8.2542***	-38.1826***	14.7736**	-0.5746	-0.3591	13.8205***	-1.5525	-31.4513***	-12.8249**	24.3236***
	(3.9712)	(3.0307)	(11.5786)	(6.1281)	(3.8441)	(2.4988)	(3.9596)	(2.0559)	(6.0180)	(6.2243)	(4.5391)
Never Smoker	-1.6279	8.7992***	-22.0707**	5.8724	-0.7160	3.2255	8.7373***	3.6566*	-40.1582***	-17.7010***	32.6668***
	(3.4956)	(2.5509)	(10.3362)	(5.0660)	(3.2428)	(2.5384)	(3.0358)	(1.8932)	(5.4107)	(4.9371)	(3.8449)
Observations	24,129	24,129	24,129	24,129	24,129	24,129	24,129	24,129	24,129	24,129	24,129
	Effects of Cigarette Cost – Reduced Form Estimates										
Cigarette Price	-1.8473	0.1109	-4.3686	-1.8441	2.6291*	0.8422	-2.0526	1.3512	-2.7405	-0.8968	1.1247
	(1.6237)	(1.6291)	(4.5748)	(2.7080)	(1.4674)	(1.3475)	(1.6262)	(1.0474)	(2.2681)	(2.4462)	(1.9662)
Observations	56,528	56,528	56,528	56,528	56,528	56,528	56,528	56,528	56,528	56,528	56,528

Notes: See notes to Table 3.

Table 7: Placebo Effects of Cigarette Price for Male, Unmarried Never-Smokers, ATUS / CPS-TUS 2003-2012

Outcome	**Any Recreational Exercise**	**Exercise**	**Non-Work**	**Work**	**Sleeping**	**Personal Care**	**Housework**	**Childcare**
Cigarette Price	0.0024	-5.3437	0.5757	34.5754	-7.4463	2.2021	0.4021	2.7081
	(0.0164)	(14.8122)	(21.4135)	(25.4310)	(5.3223)	(4.7928)	(13.2051)	(4.6218)

Outcome	**Adult-Care**	**Education**	**Purchasing Goods & Services**	**Eating & Drinking**	**Television**	**Socializing & Relaxing**	**Other**
Cigarette Price	1.3706	7.3961	-2.5770	-2.6699	5.7432	-2.1292	-0.4701
	(3.3992)	(10.9745)	(3.1942)	(2.9276)	(8.9801)	(15.9008)	(6.3689)

Notes: See notes to Table 3. All outcomes except for "Any Recreational Exercise" are measured in MET-adjusted minutes. Sample size is 5,272 observations.

never-smokers.[36] Finding significant non-zero price effects for this group would indicate that we have not adequately accounted for time-varying state-level unobservables. It is therefore validating that we do not find any economically or statistically significant effects for any of our outcomes.

We implemented several additional checks to assess plausibility and verify that our results are robust to alternative specifications (results not reported). First, all estimates are robust to alternative estimation via probit or logit regression for participation models and via Poisson or negative binomial regression for models of duration. Second, we also estimate models controlling for state-specific linear trends; while these estimates are far less precise, they do not change the general pattern of results and our conclusions. Finally, we employ state-specific cigarette excise tax rates in lieu of prices as a source of exogenous variation in smoking cessation. Due to reduced identifying variation, these estimates are also less precise, though they are fully robust with respect to direction, patterns across demographic groups, and magnitudes (adjusted for the tax elasticity in lieu of the price elasticity).

VII. Conclusion Remarks

Our study adds to the limited research on the relationship between smoking, and policies designed to reduce it, and physical activity by considering broader measures of physical activity and using more current, precisely measured data. The three previous studies of cigarette price/tax effects on adult exercise behavior find conflicting results, and all use 'exercise' measures from the BRFSS, which are somewhat ambiguously defined and are unavailable in detail during 2001-2010, a period when cigarette prices were increasing rapidly (Courtemanche 2009, Wehby and Courtemanche 2013, and Conway and Niles 2017). By using 2003-2012 data on physical activity and smoking from the American Time Use Survey and the CPS Tobacco Use Supplement, we provide a critical update using physical activity measures that are both more precise and more comprehensive. This broader view of physical activity requires a more expanded conceptual framework than previously offered, one that recognizes that smoking is an activity that can be performed simultaneously with other activities. This framework reveals an additional mechanism for smoking, and by extension tobacco policy, to have an effect on physical activity: by affecting

[36] We exclude married males since research (see for instance, Colman and Dave 2013) finds important spousal spillovers with respect to time allocation within married households.

each activity's 'value' in terms of facilitating smoking time or intensity. It also suggests that other types of physical activity beyond 'formal exercise' could be affected even if individuals do not consider their possible health benefits.

Our results suggest that the relationships between cigarette costs, smoking and physical activity are different between men and women and that focusing only on 'exercise,' rather than all forms of physical activity, may yield misleading conclusions. While smoking cessation is associated with increased 'exercise' for both men and women, only men's smoking behavior is significantly affected by cigarette prices. It therefore follows, and our reduced form estimates confirm, that increased cigarette costs only have a significant effect (an increase) on men's exercise behavior. The magnitude of the effect is also meaningful. A one dollar increase in the cost of cigarettes is estimated to increase men's probability of exercising on the surveyed day by 1.2 percentage points, a more than 6% increase, for an overall elasticity of 0.33. Considering broader measures of physical activity reveals that much of this increase may come at the expense of other forms of physical activity. Hence, when we analyze a comprehensive measure of all non-work related physical activity, we largely find no significant or meaningful effects of smoking cessation or cigarette costs.

The question of how cigarette taxes and exercise/physical activity are related has strong implications for two of the most pressing U.S. health concerns, the growing rate of obesity and the lack of adequate physical activity. Taking a more comprehensive view of physical activity, one that captures both exercise and other non-work activities, we find negligible spillover effects from cigarette costs. This non-result is not too surprising given the widely found, waning price-responsiveness of smoking and that, even if cigarette costs induce an increase in exercise – as they appear to do for males – this increase comes at the expense of other activities, further diminishing any possible impact. Understanding exactly how men and women make decisions about smoking and physical activity, more broadly defined, is therefore central to devising policies to combat these concerns and is worthy of future investigation. Future research should also consider the role of electronic cigarettes in driving smoking cessation, and how the shift from smoking to vaping vs. smoking to tobacco abstinence is impacting former smokers' health behaviors.

References

Adda, Jerome and Francesca Cornaglia. "Taxes, Cigarette Consumption, and Smoking Intensity." *American Economic Review* 96(4) 1013-28.

Adda, Jerome and Francesca Cornaglia. "The Effects of Bans and Taxes on Passive Smoking." *American Economic Journal: Applied Economics,* 2(1), January 2010, 1-32.

Baum, Charles L. "The Effects of Cigarette Costs on BMI and Obesity." *Health Economics* 18 (2009) 3-19.

Augustson, E. M., Barzani, D., Finney Rutten, L. J., & Marcus, S. (2008). Gender differences among hardcore smokers: an analysis of the tobacco use supplement of the current population survey. *Journal of Women's Health*, *17*(7), 1167-1173.

Blackwell, Debra and Tainya C. Clarke, "State Variation in Meeting the 2008 Federal Guidelines for Both Aerobic and Muscle-strengthening Activities Through Leisure-time Physical Activity Among Adults Aged 18–64: United States, 2010–2015," *National Health Statistics Reports,* No. 112, June 28, 2018.

Cadilhac, Dominique A., Toby B. Cumming, Lauren Sheppard, Dora C. Pearce, Rob Carter and Anne Magnus. "The Economic Benefits of Reducing Physical Inactivity: an Australian Example." *International Journal of Behavioral Nutrition and Physical Activity* 8 (2011) 1-8.

Callison, K., & Kaestner, R. (2014). Do higher tobacco taxes reduce adult smoking? New evidence of the effect of recent cigarette tax increases on adult smoking. *Economic Inquiry, 52*, 155–172.

Cawley, J., & Ruhm, C. J. (2011). The economics of risky health behaviors. In *Handbook of health economics* (Vol. 2, pp. 95–199). Elsevier.

Chaloupka, Frank J. and Kenneth E. Warner. "The Economics of Smoking." in Anthony J. Culyer and Joseph P. Newhouse, eds, *Handbook of Health Economics* Vol 1B. Amsterdam: Elsevier Science, North-Holland (2000) 1539-1627.

Chou, Shin-Yi, Michael Grossman and Henry Saffer. "An Economic Analysis of Adult Obesity: Results from the Behavioral Risk Factor Surveillance System." *Journal of Health Economics* 23 (2004) 565-87.

Chou, S.-Y., Grossman, M., & Saffer, H. (2006). Reply to jonathan gruber and michael frakes. *Journal of Health Economics, 25*, 389–393

Colman, Gregory J. and Dhaval M. Dave. "Exercise, Physical Activity, and Exertion Over the Business Cycle." *Social Science & Medicine*, September 2013, 93, 11-20.

Conway, Karen Smith and David P. Niles. "Cigarette Taxes, Smoking – and Exercise?" *Health Economics*, 26(8), August 2017, pp. 1019-36.

Courtemanche, Charles. "Rising Cigarette Prices and Rising Obesity: Coincidence or Unintended Consequence?" *Journal of Health Economics* 28 (2009) 781-98.

Dave, D., & Saffer, H. (2013). Demand for smokeless tobacco: Role of advertising. *Journal of Health Economics, 32*, 682-697. doi:https://doi.org/10.1016/j.jhealeco.2013.03.007

Dave, Dhaval, Daniel Dench, Michael Grossman, Donald S. Kenkel, and Henry Saffer. "Does e-cigarette advertising encourage adult smokers to quit?." *Journal of Health Economics* 68 (2019): 102227.

DeCicca, Philip and Logan McLeod. "Cigarette Taxes and Older Adult Smoking: Evidence from Recent Large Tax Increases." *Journal of Health Economics* 27 (July 2008) 918-29.

deRuiter, Wayne and Guy Faulkner. "Tobacco Harm Reduction Strategies: the Case for Physical Activity." *Nicotine & Tobacco Research*. April 2006, 8(2), 157-68.

Floro, Maria Sagrario and Marjorie Miles. "Time Use, Work and Overlapping Activities: Evidence from Australia." *Cambridge Journal of Economics*. 2006, 27(3), 881-904.

Gruber, Jonathan, and Michael Frakes. "Does Falling Smoking Lead to Rising Obesity?" *Journal of Health Economics* 25 (2006) 183-97.

Humphreys, Brad R., and Jane E. Ruseski. "An economic analysis of participation and time spent in physical activity." *The BE Journal of Economic Analysis & Policy* 11, no. 1 (2011).

Kaczynski, Andrew T., Stephen R. Manske, Roger C. Mannell, and Keerat Grewal."Smoking and Physical Activity: A Systematic Review." *American Journal of Health Behavior.* 2008, 32(1), 93-100.

Kalenkoski, Charlene M. and Gigi Foster. "The Multitasking of Household Production," *Australian School of Business Research Paper No. 2010 Econ 02*, 2010.

Meltzer, David O. and Anupam B. Jena. "The Economics of Intense Exercise." *Journal of Health Economics*. 2010 May; 29(3): 347-352.

Nguyen, Hai V. "Workplace Smoking Bans and Weekend Smoking." mimeo, July 2012.

Nonnemaker, James, Eric Finkelstein, Mark Engelen, Thomas Hoerger and Matthew Farrelly. "Have Efforts to Reduce Smoking Really Contributed to the Obesity Epidemic?" *Economic Inquiry,* April 2009, 47(2), 366-76.

Orzechowski, W., & Walker, R. (2012). The tax burden on tobacco: Historical compilation 2012 (Vol. 47). *Arlingt. Va Orzechowski Walk. Consult*.

Papathanasious, George, Dimitris Georgakopulos, George Georgoudis, Despina Perraea, and Andeglos Evangelou. 2007. "Effects of chronic smoking on exercise tolerance and on heart rate-systolic blood pressure product in young healthy adults." *European Journal of Preventive Cardiology.* October 2007 vol 14 no 5. 646-652. http://cpr.sagepub.com/content/14/5/646.abstract. Accessed 23 March 2012.

Perkins, K. A., Grobe, J. E., Fonte, C., & Breus, M. (1992). "Paradoxical" effects of smoking on subjective stress versus cardiovascular arousal in males and females. *Pharmacology Biochemistry and Behavior*, *42*(2), 301-311.

Perkins, K. A., & Scott, J. (2008). Sex differences in long-term smoking cessation rates due to nicotine patch. *Nicotine & Tobacco Research, 10*, 1245–1251.

Radtke, Theda, Urte Scholz, Roger Keller, Barbel Knauper and Rainer Hornung."Smoking-specific compensatory health beliefs and the readiness to stop smoking in adolescents." *British Journal of Health Psychology.* September 2011, 16, 610-25.

Ruhm, Christopher J. "Healthy living in hard times." *Journal Of Health Economics* 24, no. 2 (2005): 341-363.

Sen, Anindya, Mahidiyeh Entezarkheir, and Alan Wilson. "Obesity, Smoking, and Cigarette Taxes: Evidence from the Canadian Community Health Surveys." *Health Policy* 97 (2010) 180-186.

Sen Choudhury, Rebecca and Karen Smith Conway, "The Effects of Tobacco Policies on Youth Smoking and Physical Activity," *Economics & Human Biology*, 38, August 2020, #100872.

Sumner, D. A. (1981, 10). Measurement of Monopoly Behavior: An Application to the Cigarette Industry. *Journal of Political Economy, 89*, 1010-1019. doi:10.1086/261017

Tauras, John A. "Smoke-free Air Laws, Cigarette Prices and Adult Cigarette Demand." *Economic Inquiry* 44(2) (2006) 333-42.

Wehby, George L. and Charles J. Courtemanche. "The Heterogeneity of the Cigarette Price Effect on Body Mass Index." *Journal of Health Economics*, September 2012, 31(5), 719-29.